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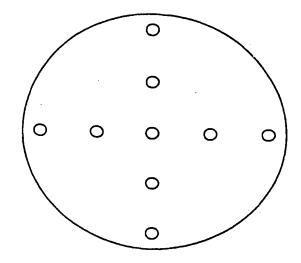
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(54) High-purity copper sputtering targets and thin films

(57) There is provided copper targets for sputtering capable of forming a deposition film with low electric resistance indispensable for high-speed operation elements and also with excellent thickness uniformity, and such thin copper films. A high-purity copper sputtering target is characterized by comprising up to 0.1 ppm each Na and K, up to 1 ppm each Fe, Ni, Cr, Al, Ca, Mg, up to 5 ppm each carbon and oxygen, up to 1 ppb each U and Th, and, excluding gaseous constituents, more than 99.999% copper. Preferably the average grain size on the sputter surface is 250 μm or below, with its dispersion within plus or minus 20%. I(111)/I(200) of X-ray diffraction peak intensity on the sputter plane is at least 2.4 with its dispersion within plus or minus 20%.





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Description Tagging and I was in dust into a 1.0 of our phase according to the treatment or gold generation according to the

[Background of the invention]

This invention relates to a high-purity copper sputtering target for the manufacture of thin film deposition materials. on semiconductors as in large scale integration and relates also to a thin high-purity copper films of low-resistivity obtained by sputtering with such high-purity copper sputtering target. See 1971, 197

Aluminum or aluminum alloy (e.g., silicon-containing aluminum) has commonly been used as a wiring material for semiconductor integrated circuits and the like. However, such materials are presenting problems including increased resistance value and electromigration of wirings due to the recent tendencies toward higher degrees of integration which results further miniaturization of elements and the wirings. There have been some attempts to replace aluminum by a refractory metal such as molybdenum or tungsten, but their greater specific resistivities are a drawback.

Attempts have also been made to use copper in place of aluminum to take the advantage of its lower resistivity and greater resistance to electromigration. Nevertheless, pure copper can hardly be employed as a wiring material because it easily oxidizes and is highly reactive with silicon and silicon dioxide films. In the research for the development of copper wiring materials, therefore, emphasis has been laid on an improvement in the oxidation resistance of copper by the controlled addition of another specific element or elements. Most of the researches are directed to the coating of the resulting thin film with an oxide (or nitride) of the added element so as to prevent further oxidation of the film under the coat.

For example, Japanese Patent Application Kokai No. 64-59938 proposes a method which consists of depositing a wiring pattern of an alloy of copper and at least one element chosen from among Ti, Zr, Al, B, and Si, and annealing the deposited wiring pattern in a nitrogen-containing atmosphere whereby a substance that forms the alloy with copper is Charles a wind to the death. Jordin. diffused over the surface to form a nitride barrier.

Patent Application Kokai No. 6-177128 discloses a thin film wiring material of a copper alloy containing 0.02-20 atom% Al or Si. The alloy is oxidized to form an oxide film in which Alfor Si is diffused and concentrated on the wiring surface so as to enhance the oxidation resistance of the surface. Subnoclares of all the property of the oxidation resistance of the surface.

A major problem common to the abovementioned methods is an increase in electric resistance by the addition of another element. An increased electric resistance retards signal transmission and adds to the power consumption. For this reason it has been necessary to put an upper limit to the proportion of the additional element so that the electric (3) mandition in L. elements each as Ra, Ni, and Ot. resistance is as low as that of pure Al, i.e., 2.7 μ Ω \bullet cm or less.

As noted above, the efforts to make use of copper as a wiring material have depended largely upon the addition of a specific element, and few attempts have been made to use pure copper itself. However, the recent progress in device structures and barrier materials are altering the situation. For one thing, modern technologies including chemical mechanical polishing (CMP) have simplified device construction and enabled the use of devices with seemingly low oddation resistance according to ordinary standards. For the other, the development of new barrier materials exclusively designed for copper has raised pure copper to a level high enough for practical use as a wiring material.

Under these circumstances the wiring deposition of pure copper that had been regarded as almost impossible is Check in Jeru Yikin spirit or least, leaf now rapidly gaining practicality.

In reality, however, the past scanty research on wiring deposition of pure copper has given little impetus to the study of the conditions required of copper wiring material; especially as a material for sputtering target. It should be pointed out, above all, that no copper sputtering target has been developed which has low enough electric resistance for the element that performs high-speed operation for a computer of the like and which is capable of forming a thin film with element that performs high-speed operation in a complete or all shorts and the performance of the performanc

[Object of the invention]

Substitute (See Section 1) years from the inventional substitution of the inventional substitution of the inventional substitution of the inventional substitution of the invention deposition. It is an object of the present invention to provide copper sputtering targets capable of forming wiring deposition films having excellent thickness uniformity as well as the low electric resistance essential for high-speed operation elements and also provide such thin copper films.

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[Summary of the invention] The term of the recorded becomes the cales of the invention.

After an intensive research, the present inventors have now found that, in order to produce a film of low enough electric resistance, the impurity contents in the target must be kept below certain numerical values. It has also been found necessary to limit down to certain levels the proportions of the elements that have been added for alloying purposes and, if the uniformity of film thickness is to be attained; the dispersions of grain size and crystalline orientation of the target must be controlled. 33% of and many agencies with appropriate of the charget must be controlled. On the basis of these findings, this invention provides no search in mill to not be as a continuity and or all the same and

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- 1. A high-purity copper sputtering target characterized by comprising up to 0.1 ppm each Na and K, up to 1 ppm. each Fe. Ni. Cr. At. Ca. Mg. up to 5 ppm each carbon and oxygen, up to 1 ppb each U and Th, and, excluding gaseous constituents, more than 99.999% copper.
- 2. A sputtering target according to 1 above wherein the average grain size on the sputter surface is 250 µm or below and the dispersion of the average grain size from location to location is within plus or minus 20%.
- 3. A sputtering target according to 1 or 2 above wherein the ratio, I(1,11) / I(200), of the X-ray diffraction peak intensity ((111) on the (111) plane to the X-ray diffraction peak intensity ((200) on the (200) plane is at least 2.4 and the dispersion of the ratio I(111)/I(200) in the sputter surface is within plus or minus 20%.
- 4. A sputtering target according to any of 1 to 3 above wherein X-ray diffraction peak width at half height in the sputter surface on the (111) plane is:20 ≤ 0.3 deg.aaipnappnar imphar professional actions as a second action of the contraction o
- 5. A sputtering target according to any of 1 to 4 above wherein it also contains up to 5 ppm each Si, Ag, Ti, Zr, Hf, enum or tungstern, but their greater snecklid resistivities ale archaetas.
- 6. A sputtering target according to any of 1sto 5 above wherein it has an electric resistance of 1.9μ Ω cm or less.
- A sputtering target according to any sputtering target according to an electric resistance of 2.0μ Ω cm or less produced by sputtering target according to any sputtering target according to acc tering with a high-purity copper sputtering target according to any-of it to 6 above.

remediate materials, the hore, emphasis has been laid on an improvement in the exidation resistance or occase to Brief explanation of the drawing percent of the rest of the rest and the rest and the drawing percent of the rest and the rest of the rest and the rest of the res coxide (or chiride) of the edded election so as to prevent further paids from of the tilm under the

FIG. 1 is a schematic view of a target, showing points of sampling for the investigation of its characteristics.

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The invention will now be described in detail.

The invention will now be described in detail.

The high-purity copper sputtering target of this invention has an impurity content seduced to a minimum.

In order to ensure the reliability of performance of a semiconductor device formed by sputtering, it is important to minimize the proportion of impurities deleterious to semiconductor devices. Particularly deleterious impurities include: To be set if a particular of the set of a set of the se

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- (1) alkali metal elements such as Na and Kiats notesimens a langia horrows and test applieds notice of the me
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- (3) transition metal elements such as Fe, Ni, and Cr.

than't to the conservation as a wiring material have depended largely upon the addition of Alkali metal elements such as Na and K are especially diffusible and migrate easily through a insulation film, with the possibility of causing deterioration of MOS-LSI interface characteristics. Their proportions, therefore, should be lim-

y a grant of plate states, 2.7 just a circlor less.

ited to at most 0.1 ppm each, preferably 0.02 ppm eachdans bus notion tance solved solliarities and (50.5) and a Radioactive elements such as Usand Thremit alpha rays which can be responsible for soft errors of semiconductor elements. That is why their proportion should be severely controlled, to 1 ppb or less, preferably to 0.5 ppb or less, each. Transition metal elements such as Fe, Ni, and Cr too can cause troubles of interface connections. Hence their pro-

portions should be 1 ppm or less, preferably 0.1 ppm or less, each.

Besides these elements, particularly those harmful to semiconductor elements, other impurities must also be minimized. Generally, electric resistance is a function of the impurity level and the smaller the impurity content the lower the electric resistance. Thus, in order to lower the electric resistance, a higher purity is desirable. When the actual cost of producing a sputtering target and other considerations are taken into account, it would be of great practical value to control the impurity level so that the resulting thin film shows an electric resistance below 2.0 μ Ω • cm tranction and the resulting thin film shows an electric resistance below 2.0 μ Ω • cm tranction and the resulting thin film shows an electric resistance below 2.0 μ Ω • cm tranction and the resulting thin film shows an electric resistance below 2.0 μ Ω • cm tranction and the resulting thin film shows an electric resistance below 2.0 μ Ω • cm tranction and the resulting thin film shows an electric resistance below 2.0 μ Ω • cm tranction and the resulting thin film shows an electric resistance below 2.0 μ Ω • cm tranction and the resulting thin film shows an electric resistance below 2.0 μ Ω • cm tranction and the resulting thin film shows an electric resistance below 2.0 μ Ω • cm tranction and the resulting thin film shows an electric resistance below 2.0 μ Ω • cm tranction and the resulting thin film shows an electric resistance below 2.0 μ Ω • cm tranction and the resulting thin film shows an electric resistance below 2.0 μ Ω • cm tranction and the resulting thin film shows are resulting the resulting thin film shows an electric resistance below 2.0 μ Ω • cm tranction and the resulting thin transition and the resulting thin film shows an electric resistance and the resulting thin transition and the resulting thin transition and the resulting the resulting the resulting thin transition and the resulting the resulting

Thus not only the heavy metal elements but also such light metal elements as Al, Ca, Mg must be reduced in proportions, to 1 ppm or less, preferably 0.1 ppm or less, each.

Gaseous ingredients such as carbon and oxygen too are undesirable in that they increase the electric resistance of the resulting film and have adverse effects upon the surface configuration of the film. The carbon is included herein as a gaseous ingredient since it is a gasifiable ingredient. Their contents should be kept to 5 ppm or less, preferably 1 ppm or less, each.

Research has suggested the desirability of minimizing also the proportions of Si, Ti, Zr, Hf, B, and Ag that have been often added as alloying elements, for the sake of reduced electric resistance. Their proportions should be 5 ppm or less, preferably 0.5 ppm or less, each.

The overall copper purity, excluding the gaseous ingredients should be at least 99.999%.

The overall copper purity excluding the gaseous ingredients around be at least 99,995%. The dispersions of the uniformity in thickness of the film that is formed by sputtering, it is essential to restrict the dispersions of the crystalline grain size and orientation of the target memele entro anothogona entralevel misman

As for the grain size, both the average grain size in the sputter surface and the variation of the average grain size from location to location influence the uniformity of film thickness. If the average grain size is greater than 250 µm, it is no longer possible to limit the average dispersion of film thickness on an 8-in wafer to 2.0 or less. A locational variation

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in excess of 20% is undesirable either, because the average dispersion of film thickness exceeds 2.0 even though the ways file average grain size is below 250 µm. Thus, an average grain size in the sputter surface of 250 µm or below, and; a locational variation in the average grain size of not exceeding plus or minus 20% are requisites for the realization of film thickness uniformity.

On the other hand, crystalline orientation too has similar influences upon the uniformity of film thickness. The Joint Committee of Power Diffraction Standard (JCPDS) reports that a wholly random orientation gives an X-ray diffraction.

Deak intensity (1111)/I(200) = 2.08. Investigations by the present inventors, however, have revealed that intensified criestation in the (1111) plane rather than wholly random orientation produces better film thickness uniformity. The reason, is as follows:

The sputtering rate depends on the plane of orientation. The sputtering rate thus varies from location to location where the orientation is at random, resulting in less uniformity of film thickness than with the orientation in a specific plane. In the case of copper, the (111) plane is the densest of its crystallographic planes, where the density of the sputtered atoms released is higher than in the other planes, leading to superior film thickness uniformity.

A work deformed layer of the target surface is another factor influencing the film deposition characteristic. The term "work deformed layer of the target surface" is used to mean a layer of the target surface with fractured crystallinity or microcracks and other flaws formed under the pressure of a cutting tool during machining (usually on a lathe). The presence of a work deformed layer is known to have unfavorable effects; e.g., instable deposition rate, increased film resistance, and inadequate film thickness uniformity. These effects can be avoided by presputtering the work deformed layer immediately before ordinary sputtering. The present inventors have improved the film deposition performance by machining each target in such manner as to minimize its deformed layer. Since the presence of a deformed layer expands the half width of X-ray diffraction, the present inventors estimated the volume of the deformed layer present from the X-ray diffraction peak width at half height. It has been found as a result that, if a favorable deposition performance is to be secured, it is necessary that the X-ray diffraction peak width at half height in the sputter surface on the (111) plane be 29 ≤ 0.3 deg.

Such a high-purity copper target with a minimized impurity content and outstanding film thickness uniformity as an described above can be made in the following way. One can be said the said th

Ordinary electrolytic copper is electrorefined in a bathlof sulfuric acid or nitric acid to reduce the impurity content, and the and attain a high-purity level of at least 99.9999%. The copper is then vacuum induction melted and a high-purity copper ingot is obtained. The ingot is hot worked by hot forging, hot rolling, etc., cold worked by cold rolling, cold forging, and the ingot is hot worked by hot forging, he rolling, etc., cold worked by cold rollings cold forging, he was a second rolling and the cold rolling are cold r etc., and then heat treated. Hot working to a working ratio of 50% or more, cold working to a ratio of over 30%, and heat treatment at 350-500°C for 1-2 hours are desirable. The hot working is indispensable for destroying the cast structure and refining and adjusting the ingot to a structure of equiaxed grains. Once the cast structure has been destroyed, cold working and heat treatment are carried out under strictly controlled conditions to refine the grain size and control the crystalline orientation. The cold working ratio influences the grain size after the heat treatment, and the greater the working ratio the finer will be the grains to be obtained. It is effective too in attaining a crystalline orientation as desired. Meanwhile, the material begins to harden owing to work hardening as the working ratio increases. The hardening beyond a certain level can cause cracking during the course of working. For these reasons the cold working ratio should be at most about 90%. The temperature and time for the heat treatment have certain bearings upon the grain size after ment have certain bearings upon the grain size after ment have certain bearings. recrystallization. Proper choice of heat treatment conditions renders it possible to obtain a copper plate having a desired grain size. A too low temperature should be averted because it would effect insufficient recrystallization and and a series of produce a structure not thoroughly freed from working strains. Too high a temperature, on the other hand, induces grain growth which coarsens the crystal grains. The time for heat treatment has a less significant influence on the structure and, taking the productivity into consideration, a duration of one or two hours is adequate.

Following the heat treatment, the copper plate is lathed or otherwise machined to a target shape. The machining conditions must be carefully controlled since they dictate the formation of a deformed layer in the final product. Recommended lathing conditions are: turning velocity, 40-80 rpm; cutting tool feed, 0.1-0.2 mm; and depth of cut, 0.1-0.2 mm. Machining conditions are correlated with productivity, and high-speed operation is beneficial for productivity but can lead to the inclusion of a deformed layer. Hence the above-mentioned conditions are desirable. The copper plate that has been machined to a desired shape is then bonded to a backing plate and is ready for use as a sputtering target.

[Examples]

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The invention is illustrated by the following examples and comparative examples. The invention is illustrated by the following examples and comparative Examples 2-3, targets were made each from a high-purity copper ingot obtained by electrorefining an electrolytic copper in a nitric acid bath and their melting by vacuum induction. Comparative Exam-

The above mentioned flar jets 7 to Gibert gram citats with dispersions and diffriction pusit introvity rank.

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ple 1 represents a target made from a low-purity copper ingot. The targets were in the form of a disk each, measuring 12.98 in. inidialmeter and 6:35.mm thick: a set of each or other estimates growing against the form of a disk each, measuring 12.98 in. inidialmeter and 6:35.mm thick: a set of each or other as a sign of each or other as a set of each or other as a sign or has one of the each of each or other as a sign of each of the each of each or other as a sign of each of the each of each of each or other as a sign of each of each or other each of each of each or other each or other each of each or other each or other each or other each of each or other each or other each or other each of each or other each of each or other each or other each or other each or other each of each or other each or o

(Example 1) Target A

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The same ingot as used in Example 1 was not rolled at 600°C to dimensions 300 mm dia, and 15 mm thick and then cold rolled to 360 mm dia, and 10 mm thick. The resulting plate was heat treated at 400°C for one hour, and under the same conditions as in Example 1, a target was made to heat a notice to be set it as about 10 mm thick. The resulting plate was heat treated at 400°C for one hour, and under the same conditions as in Example 1, a target was made to heat a notice to be set if a pairway to be set in the same conditions as in Example 1, a target was made to heat a notice to be set in the same conditions as in Example 1, a target was made to heat a notice to be set in the same conditions as in Example 1, a target was made to heat a notice to be set in the same conditions as in Example 1, a target was made to heat a notice to be set in the same conditions as in Example 1, a target was made to heat a notice to be set in the same conditions as in Example 1, a target was made to heat a notice to be set in the same conditions as in the same con

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Starting with the ingot of Example 1, the process steps of Example 1 were followed down to cold rolling. The rolled plate was heat treated at 550°C for one hour and then subjected to the same machining conditions as in Example 1 to make a target? A set the process at the parameter of the plate was heat treated at 550°C for one hour and then subjected to the same machining conditions as in Example 1 to make a target? The process are set to the process at the plate of the process at the plate of the process steps of Example 1 to plate of the plate

(Example 4) Target Depres in the stripe of risdict of both was a contractible X-ray that the X-ray and some of the X-ray that the X-ray and the X-ray of the X-ra

The same ingot as used in Example 1 was hot forged, cold rolled, and hot rolled under the same conditions of Example 1 to obtain a disk-shaped copper plate 360 mm dia. and 10 mm thick. This copper plate was lathed at a speed of 70 rpm, cut of depth of 0.4 mm and tool feed of 0.3 mm to the shape of a target.

property the elost an actor (1.5. 86%). The copper is then vacuum induction melted and a high-pully, στρησια αυτο είναι είναι το και by hot forging, hot rolling, etc., cold worked by a tegral (Relamina Administración).

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(Comparative Example 2) Target Finder took additional actioning and second that the best and the magnificant in the comparative Example 2) Target Finder took additional action in the comparative Example 2) Target Finder took additional action in the comparative Example 2) Target Finder took additional action in the comparative Example 2) Target Finder to additional action in the comparative Example 2) Target Finder to add the comparative Example 2) Target Fi

The same ingot of the 99.95% purity as used in Comparative Example 1 (157 mm dia. and 60 mm thick) was not rolled at 600°C to a size 360 mm dia. and communication methods. Without a subsequent heat treatment, the work was lathed under the same conditions as in Example 1 to make a target at the mass of sold and sold as a second sold as a secon

Becyclinication. Proper choice or hear treatment conditions renders it possible to obtain a copper plate having a series of the conditions are the conditions of the conditions are the conditions are the conditions of the conditions are the conditions of the condit

The ingot of the 99.95% purity as used in:Comparative Example 1 (157, mm dia. and 60 mm thick) was not rolled at 600°C to dimensions 265 mm dia. and 20 mm thick and then cold rolled to 360 mm dia. and 10 mm thick. Without a heat treatment but under the same conditions as in Example 1 the work was lathed to a target.

country such be carvelly accounted they dictate the formation of a deformed layer in the linear product. Perconance in the linear product. Perconance in the linear product sead of the season of the

gention is beneficial for prefered of the productivity, and high-speed operation is beneficial for productivity but decidence or the productivity of the production of the productivity of the production of the produc

Target characteristics

The above-mentioned Targets A to G had grain sizes with dispersions and diffraction peak intensity ratios of the (111) plane and the (200) plane with dispersions as shown in Table 2 estomaxs private the strength of each target, samples were cut out from a total of 9 points shown in FIG. 1. Grain sizes were determined by the scission method stipulated in UIS (Japanese Industrial Standards) H501

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Film deposition test

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	• •		71.7		[Table 1]	1 -8.3		10 690	320	અંહ દ
Target	Unit	Ex. 1 A	Ex: 2 B	Ex. 3 C	Ex:40D	6Comp. Ex. 1	ΙE	Comp. Ex. 2 _. F	· Comp. Ex. 3 G	
Na	ppm	0.005	0.005	0.005	0.005	0.04		0.04	0.04	ъ j `.
К		0.005	0.005	0.005	0.005	~ 0.05		0.05	0.05	1
Fe		0.03	0.03	0.03	0.03	0.9		0.9	0.9	1
Ni ;	១៩ភ	0.008	- 0.008	0.008	- 0.008	1.0		1.0	1.0]
Cr ;		0.002	0.002-	0:002	0.002	0.1		0.1	0.1]
Al ·	1	0.04	0.04	0.04	0.04	0.05		10.05	0.05] ' . •3•• '
Ca		- 0.02	0.02	0.02	0.02	0.2	,	0.2	0.2	
Mg	1	0.01	0.01	0.01	0.01	2		2	2; '=]
С	1	0.05	0.05	005	0.05	j 33		S (1 8	1	
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Si	, ,,,,,,	0.1	0.1	0.1	0.1	5		5	5] สน.) โก
Ag	19:	#15 0.2 779	sib r0.2 no	. 5 15 0.2 000	9d 0.2 วาณ	ลเลยอกฝ ี5 tm	iit noi	isoget e 15 aneam r		15 35
Ti	1	0.03	0.03	0.03	0.03	5	37.37	5	5] ^* `
В	1	0.004	0.004	0.004	0.004	0.6		0.6	0.6	
Zr	1	0.02	0.02	0.02	0.02	7		7	7	
Hf	history.	, 0.006	ಎ, 01.006 ೧೯	.0.006	0.006 g	. ეუგე ექ 0.9 ეს	្នឧ भ	9 719 A. COO!	Hg. g. 0.9	Jir* siri
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[Table 2]

Target Character	Ex. 1 A	Ex. 2 B	Ex. 3 C	Ex. 4 D	Comp. Ex. 1 E	Comp. Ex. 2 F	Comp. Ex. 3 G	15. k
Grain size (μm)	150	200	460	150	120	250 ggg		
Dispersion of average grain size (%)	1 ±14 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	# ±19 * mld +n)	ਾਵੇ±28 ^{7†} ਮਿਤਾਸ਼ਾਅ ਤੁਸੀਂ:	no bersiur	in trionness acc:	on is meant the	THE CONTRACTOR IN MEDICAL PRODUCTIONS HELD CITE TO NAME	
l(111)/l(200)	5.2	2.5	4.8	5.2	EMU :: 5.1 / 1/2	UMACT 1.5 NUT	0.5	
Dispersion of peak intensity ratio(%)	±11	±19	±14	±11	±13	±25	±21	a - :
Half width (deg)	0.16	0.20	0.11	0.34	{7 a ·0.1/7	0.17	0.17	

* Comparative Example 3 in	volved no recrystalliz	ation; and therefore	the grain siz	a and tha dis	persion of a	verage grain	size j
could not be measured.	0.04	NO 0	800.0	0.005	800 O	200.0	ताद्व
32.4	8 0.0 ···	₹ 0 .0					
€3	3.6	Table 31	80.0	0	20.3	80.0	
i					professional contract of the first contract of the contract of		

Target	Ex. 1 A	Ex. 2-B -	Ex 3 C	Ex. 4.D	Comp. Ex. 1.E	Comp. Ex. 2 F	
Resist'y (μ Ω· • cm)	1.85 1.6	1.85	1.85	1.85 გა.ი	2.2 40.0	22	2.2 40 0
Thickness dis- tri.dispn o(%)	1.5	1.8 S	2.3	1.5	5 1.5	2.50.0	300 4.0 ;
Desposition	3	5	3	15	ē., 3 ,	a j.	₹ 3 9
thickness neces- sary for dummy		į.		á			
run* (μm)	5	a		.5	0.1	.00	T.C

	nickness for dummy ru			į."	accumulated	untii the dis	persion of the film
thickne	ss distribution reache	s the value given in:	Table 3:	F0.0	50.0	20 C	\$0.0
	E.0	Service and the service and th				00.11	\$ 0 0.7
(Results)	*	T'	No.	*	25. ()	S.J.c.	[80.6]

The films formed using the high-purity copper sputtering targets according to the invention had very low resistivities of no more than $2\mu\Omega \cdot cm$.

Excellent uniformity of film-thickness distribution was exhibited by the films formed with the targets baving an average grain size of 250 µm or less, grain size dispersion within plus or minus 20%, X-ray diffraction peak intensity ratio, I(111)/I(200), of no less than 2.4, and peak intensity ratio dispersion within plus or minus 20%.

It was confirmed that the film thickness necessary for a dummy run may not be great when the film is deposited using a target with a peak width at half height in the (111) plane of less than 0.3 deg.

[Advantages of the invention]

The high-purity copper sputtering target according to this invention is capable of producing a copper film of extremely low resistivity of no more than 2 μ Ω • cm and outstanding uniformity of film thickness distribution. Moreover, the film thickness of dummy run at the time of sputtering can be decreased.

Generally, there is a relation

 $R = \mu \cdot US$

where R: resistance,

μ: specific resistivity,

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L: length, and

S: cross sectional area.

Thus, in the case of a film with a resistivity of no more than $2\mu \Omega \cdot cm$ made in conformity with this invention, the resistance can be kept low even after wire thinning.

Also, a relation

 $Q = I^2 \cdot R$

where

Q :Joule heat, and

I : current

holds, and the current that flows being the same, the film evolves less Joule heat. Compared with a copper deposition film with a purity of 99.95%, a 99.9999%-pure copper film of the invention has a lower resistivity, by about 10%. Hence when the same circuit is made, according to the above equation, the film of this invention can reduce the quantity of Joule heat by about 10%.

Its low resistivity reduces the delay of signal transmission and effects a saving of power consumption.

Claims

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1. A high-purity copper sputtering target characterized by consisting of up to 0.1 ppm each Na and K, up to 1 ppm each Fe, Ni, Cr, Al, Ca, Mg, up to 5 ppm each carbon and oxygen, up to 1 ppb each U and Th, and, excluding gaseous constituents, more than 99.999% copper.

2. A sputtering target according to claim 1 wherein the average grain size on the sputter surface is 250 µm or below and the dispersion of the average grain size from location to location is within plus or minus 20%.

3. A sputtering target according to claim 1 or 2 wherein the ratio, I(111)/I(200), of the X-ray diffraction peak intensity I(111) on the (111) plane to the X-ray diffraction peak intensity I(200) on the (200) plane is at least 2.4 and the dispersion of the ratio I(111)/I(200) in the sputter surface is within plus or minus 20%.

A sputtering target according to any of claims 1 to 3 wherein X-ray diffraction peak width at half height in the sputter surface on the (111);plane is $2\theta \le 0.3$ deg.

A sputtering target according to any of claims 1 to 4 wherein it also contains up to 5 ppm each Si, Ag, Ti, Zr, Hf, and

A sputtering target according to any of claims 1 to 5 wherein it has an electric resistance of 1.9μ Ω • cm or less.

A thin high-purity copper film characterized by an electric resistance of $2.0\mu\,\Omega$ $\,\circ\,$ cm or less produced by sputtering with a high-purity copper sputtering target according to any of claims 1 to 6.

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EUROPEAN SEARCH REPORT

Application Number EP 98 10 9210

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